Seasonal and spatial variability of condition and length-weight relationship of European Chub (*Leuciscus cephalus*) inhabited in Upper Çoruh River (Turkey)

by

Serdar BEKTAS, Ayhan YILDIRIM & Murat ARSLAN (1)

ABSTRACT. - Seasonal and spatial variations in Fulton condition factor (K), somatic index (SI) and length-weight relationship (L-WR) for *Leuciscus cephalus* from Upper Çoruh River (Turkey) were analysed from March 2000 to February 2001. There was slightly temporal variation in both K and SI for adults and juveniles with generally lower value in summer and winter and higher value in spring. Although a considerable spatial variation in K was reported, there was no statistically difference in SI. L-WR was calculated as $W = 0.008 \times L^{3.164}$ for males, $W = 0.008 \times L^{3.176}$ for females, $W = 0.009 \times L^{3.102}$ for juveniles, and $W = 0.008 \times L^{3.162}$ for overall, indicating positive allometric growth in mature and juvenile fish. Exponent *b* value also varied both spatially and temporally. Our results suggested that condition, somatic growth, and growth characteristics of *Leuciscus cephalus* changed depending on both gonadal development and spawning properties of species and environmental condition of the basin.

RÉSUMÉ. - Variations saisonnières et spatiales de la condition et de la relation taille-poids des chevaines (*Leuciscus cephalus*) dans le cours supérieur de la rivière Coruh (Turquie).

Dans ce travail, le facteur de condition (K), les index somatiques (SI) et la relation taille-poids de *Leuciscus cephalus* du cours supérieur de la rivière Çoruh ont été étudiés de mars 2000 à février 2001. Il apparaît en général que les valeurs de K et SI des poissons matures et jeunes changent peu entre l'été et l'hiver mais sont plus importantes au printemps. Pour K, on constate une variation géographique des valeurs, mais pas de façon claire pour la valeur de SI. Les relations taille-poids sont les suivantes : pour les mâles, $W = 0{,}008 \times L^{3{,}164}$; pour les femelles, $W = 0{,}008 \times L^{3{,}176}$; pour les jeunes, $W = 0{,}009 \times L^{0{,}102}$; pour l'ensemble des individus $W = 0{,}008 \times L^{3{,}162}$. Cela traduit une allométrie positive pour la croissance des poissons matures et pour les jeunes. La valeur de l'exposant *b* de ces équations a montré des variations temporelles et spatiales. Nos résultats suggèrent que la variation de la condition et des caractéristiques de la croissance somatique de *Leuciscus cephalus* dépendent, d'une part, du développement des gonades et de la fécondation et, d'autre part, des caractéristiques écologiques du bassin.

Key words. - Cyprinidae - *Leuciscus cephalus* - Turkey - Çoruh River - Length-weight relationship - Condition.

Length-weight relationship (LW-R), condition factor, and somatic index are functional tools in fish biology because they have been analysed to estimate seasonal and temporal variability of physiological status, reproduction and growth in fish population (LeCren, 1951; Wootton, 1992; Pauly, 1993; Encina and Granado-Lorencio, 1997ab; Yildirim *et al*., 2006; Arslan and Yildirim, 2007) and could supply information about stock situation (Bagenal and Tesch, 1978). LW-R have been used to fulfill many goals such as estimating biomass from length, determining growth characteristic (isometric or allometric), comparing life histories in species and using stock assessment models in fisheries assessment (Ricker, 1975; Froese and Pauly, 1998; Moutopoulos and Stergiou, 2002). Researchers have calculated condition factor to determine physical and physiological pattern of fish like body composition, feeding, growth and reproductive status (Elliott, 1976; Costopoulos and Fonds, 1989). Somatic index have been used as a restricted indicator of the nutritional status of fish (Encina and Granado-Lorencio, 1997ab; Herrera *et al*., 1988; Yildirim *et al*., 2006; Arslan and Yildirim, 2007).

The *Leuciscus cephalus* (Linnaeus, 1758) (Pisces, Cyprinidae), also called European chub, is one of the most common and widely distributed species throughout European streams, Basin of Black Sea, Caspian Sea, Azov Sea, Caucasian region and Turkish freshwaters (Kuru, 1975; Geldiay and Balik, 1996). It is also a dominant species in Upper Çoruh River (Yildirim *et al*., 2008) and consumed by resident people. Most researchers have studied on reproductive properties, growth, and life history characteristics of European chub in different European and Turkish freshwater systems (Philippart, 1972; Penaz *et al*., 1978, Hickley and Bailey, 1982; Vitali and Braghieri, 1984; Türkmen *et al*., 1999; Erdoğan *et al*., 2002; Gül and Yilmaz, 2002; Balik *et al*., 2004). Although there are many investigations on condition and gonadal maturation of European chub (Bircan and

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(1) Department of Fisheries and Aquaculture, Ispir Hamza Polat Vocational School, Atatürk University, 25900 Ispir, Erzurum, TURKEY. [sbektas@atauni.edu.tr]

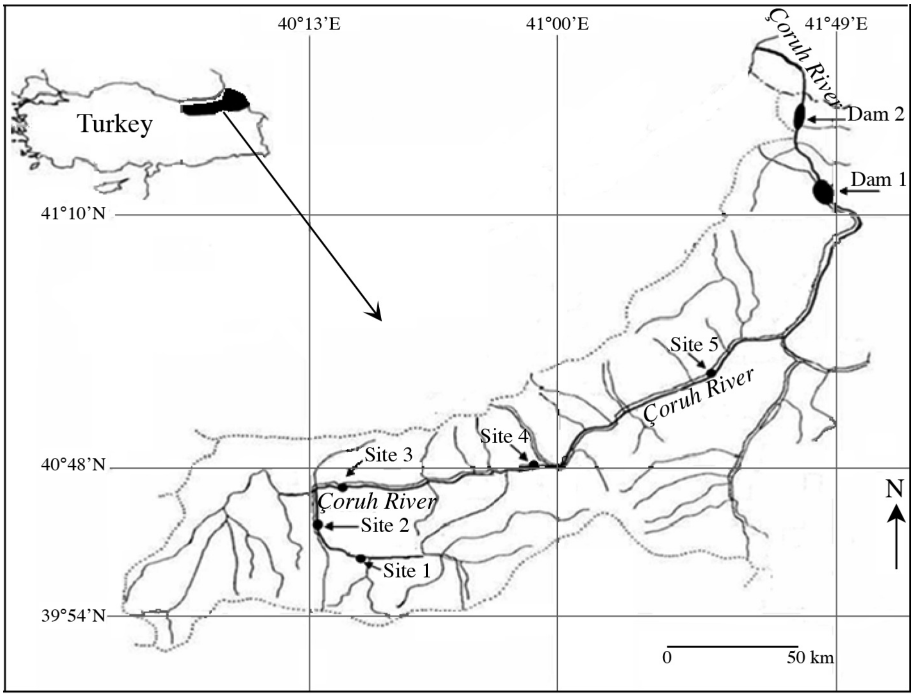

Figure 1. - Upper Coruh River (Turkey) fish sampling sites (1-5). *[Stations de prélèvement (1-5) des poissons dans la rivière du Haut Çoruh.]*

Ağirağaç, 1995; Ekmekçi, 1996, Ünlü and Balci, 1991; Libovarisky, 1979; Türkmen *et al.*, 1999; Erdoğan *et al.*, 2002; Şaşi, 2004), there is limited information about spatial and temporal changes in LW-R, condition and somatic index of juveniles and adults, separately.

In this study, seasonal and temporal measurements of condition factor, somatic index, and length weight relationship were investigated for juveniles, males, females of European chub from Upper Çoruh River located in Northeastern Turkey. To determine the physiological pattern of European chub will allow the researchers to compare this pattern before and after the dams which will be constructed on the locations where the present study was carried out in a few years because these dams will be the most important major human alteration on Çoruh basin.

MATERIAL AND METHODS

The Çoruh River has been well-described in the literatures as one of the largest rivers of Turkey, with a total length of 376 km (Yildirim *et al.*, 2001) (Fig. 1). We caught European chub from five sites, Kirik (site 1), Maden (site 2), Bayburt (site 3), Kirazli (site 4), Nihak (site 5). It courses narrow valley in sites 4-5 while the river runs throughout a large plateau in sites 1-3. Water velocity, discharge, and slope also get to increase along the gradient. Water discharge dramatically increases in spring because of the heavy rains and melting snow. Some physical characteristics of study area are given in table VI.

A total of 2196 European chub were collected monthly with electrofishing, from March 2000 to February 2001. Samples were placed on ice and transferred to the laboratory, where they were held in a freezer at -10°C for later analysis. Prior to dissection, all fish were thawed, rinsed and blotted dry, measured to the nearest 1 mm (fork length) and weighted to the nearest 0.01 g. Somatic weight (SW) was measured after gut (WS) and gonad (WG) were removed. Sexes were determined either macroscopic by eye or microscopic by microscope. The sex and the stage of maturity were determined by macroscopic examination of the gonads. Fish with well developed gonads were considered mature; juveniles did not have developed gonad.

The length-weight relationship was calculated by using $W = a \times L^{b}$. The parameters a and b were calculated by least-squares regression (Ricker, 1975). It was calculated for group that has over 10 fishes. The Fulton condition factor, K, was calculated as: $K = W \times L^{-3} \times 100$ (Anderson and Neumann, 1996). Somatic Index, SI, was calculated as: $SI = SW \times L^{-3} \times 100$ (Encina and Granado-Lorencio, 1997a).

Fish collected in March-April, May-June, July-August, September-October, and November-February were pooled into early spring (E. spring), late spring (L. spring), summer, fall, and winter, respectively. To identify allometric or isometric growth, the b value of the length-weight relations was tested for deviation from the value of 3.0 by a t-test. When b was not statistically different from 3.0, growth was considered isometric. Positive or negative allometric growth was indicated when b statistically differs from 3.0 (Ricker, 1975). Three-way ANOVA and Tukey multiple Honest significant

Table I. - Monthly variation of $\overline{K}$ for males, females and juveniles of European chub from Upper Çoruh River (Turkey). * Means with different superscript letters in a row are significantly different ($p < 0.05$). *[Variations mensuelles de* $\overline{K}$ *de* L. cephalus *de la rivière du haut-Çoruh pour les mâles, les femelles, les juvéniles et l'ensemble des individus. Les différences significatives (p < 0,05) des valeurs moyennes sont signalées par différentes lettres.]*

Month	Males		Females		Juveniles		Overall		*
	N	$\overline{K}$ ± SE	N	$\overline{K}$ ± SE	N	$\overline{K}$ ± SE	N	$\overline{K}$ ± SE	
March	106	1.38 ± 0.018	57	1.43 ± 0.026	148	1.28 ± 0.014	311	1.34 ± 0.011	a
April	88	1.37 ± 0.018	32	1.41 ± 0.035	124	1.26 ± 0.017	244	1.32 ± 0.012	ac
May	103	1.53 ± 0.019	58	1.56 ± 0.024	106	1.27 ± 0.018	267	1.43 ± 0.014	b
June	78	1.45 ± 0.016	65	1.51 ± 0.025	140	1.35 ± 0.013	283	1.42 ± 0.011	b
July	125	1.41 ± 0.017	36	1.44 ± 0.024	139	1.29 ± 0.014	300	1.36 ± 0.011	a
August	40	1.37 ± 0.020	26	1.41 ± 0.038	101	1.29 ± 0.015	167	1.33 ± 0.012	a
September	22	1.40 ± 0.033	23	1.48 ± 0.036	90	1.27 ± 0.017	135	1.33 ± 0.016	a
October	62	1.36 ± 0.018	35	1.36 ± 0.020	146	1.25 ± 0.016	243	1.29 ± 0.012	cd
November	43	1.34 ± 0.023	10	1.38 ± 0.033	104	1.22 ± 0.016	157	1.26 ± 0.013	de
December	-	-	-	-	-	-	-	-	
January	-	-	-	-	-	-	-	-	
February	19	1.40 ± 0.051	5	1.35 ± 0.058	65	1.20 ± 0.016	89	1.25 ± 0.019	e
Mean	686	1.41 ± 0.007	347	1.46 ± 0.010	1163	1.27 ± 0.005	2196	1.35 ± 0.004	
*		a		b		c			

Table II. - Results of three-way ANOVAs reflecting effect of sexes, location and month on condition factor and somatic index of European chub from Upper Çoruh River (Turkey). *[Résultats des ANOVA à trois facteurs montrant les effets du sexe, du site et du mois sur les valeurs de l'index somatique et du facteur de condition de* L. cephalus *de la rivière Çoruh.]*

	Condition Factor (K)				Somatic Index (SI)			
Source	df	Mean Square	F	Sig.	df	Mean Square	F	Sig.
Sex	2	0.827	31.84	< 0.001	2	0.138	6.245	0.002
Site	4	0.091	3.514	0.007	4	0.014	0.663	0.617
Month	9	0.263	10.141	< 0.001	9	0.163	7.395	< 0.001
Sex x Site	8	0.006	0.235	0.984	8	0.025	1.151	0.326
Sex x Month	18	0.032	1.255	0.208	18	0.024	1.114	0.332
Site x Month	35	0.126	4.848	< 0.001	32	0.100	4.556	< 0.001
Sex x Site x Month	51	0.053	2.070	< 0.001	41	0.031	1.435	0.038
Error	2068	0.025			1473	0.022		

differences (HSD) test for unequal sample sizes was used to estimate effects of sex, month, and site on condition factor and somatic index. Correlations were carried out with all the fishes collected through the annual cycle. For all tests, statistical significance was based on $p < 0.05$.

RESULTS

Mean condition factor for males, females, juveniles and overall was 1.41, 1.46, 1.27, and 1.35, respectively and statistically significant differences were observed among sexes (Tab. I). Three-way ANOVA showed that there were considerable temporal and spatial variations in K (Tab. II). Moreover, K value in site 2 was higher than that in other sites. K values in adults were more fluctuated than those in juveniles. Those for adults were relatively high in E. spring and L. spring with a decrease in summer (July-August), trended to increase in September and reached its lowest level in winter (November-February). K in juveniles was more stable with higher values in spring and summer and lower values in fall and winter months (Fig. 2).

Three-way ANOVA showed that there was significant temporal variation in S ($p < 0.05$) whereas no significant spatial changes were found. There was similar fluctuation in males and females and the highest value occurred in late spring and lowest values were experienced in winter months (Tab. IV). Additionally, fluctuation in SI for juveniles was more stable than that for adults.

L-WR for males, females, juveniles, and overall was $W = 0.008 \times L^{3.164}$, $W = 0.008 \times L^{3.176}$, $W = 0.009 \times L^{3.102}$, and $W = 0.008 \times L^{3.162}$, respectively. All sexes showed positive allometric growth. However, there was considerable variation in *b* value of LR-W both spatially and temporally. Most fishes in all sites demonstrated positive allometric growth except females from site 2, males from sites 4 and 5, and juveniles from site 4 having isometric growth (Tabs IV, V).

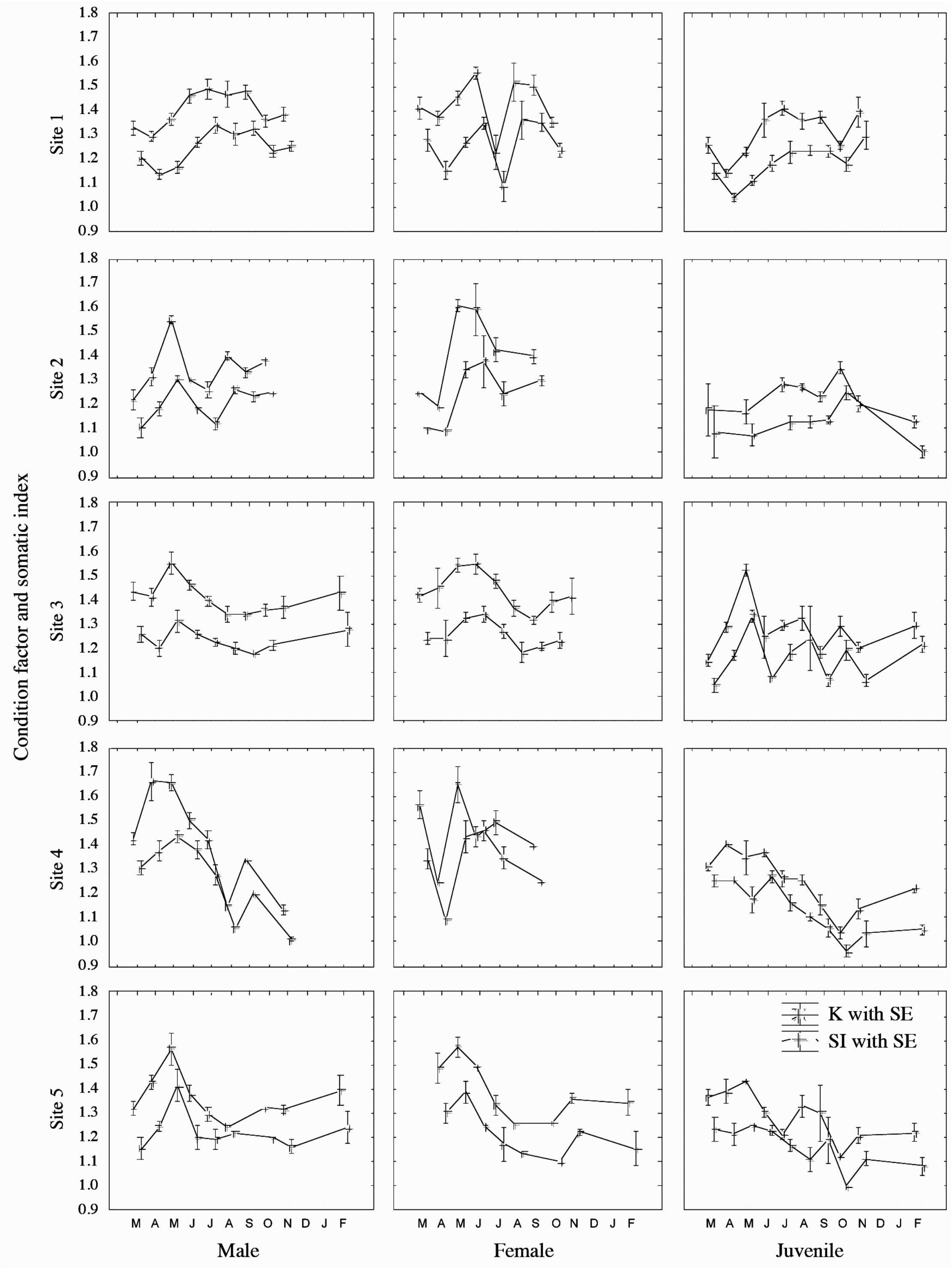

Figure 2. - Monthly variability of K and SI (± SE) by sexes and sites from Upper Çoruh River (Mar. 2000-Feb. 2001). *[Variations mensuelles des valeurs de K et SI (± SE) des* L. cephalus *de la rivière Çoruh en fonction du sexe et des sites.]*

DISCUSSION

Many freshwater fish inhabiting European waters exhibited seasonal condition, nutrition, and somatic energy cycle through the year which usually are related to temporal variation in environmental condition, such as water temperature, production cycle, food supply with reproduction cycle in fish (Pierce *et al.*, 1980; Encina and Granado-Lorencio, 1997a,

Table III. - Monthly variation of somatic index (SI) for sexes of European chub from Upper Çoruh River (Turkey). * Means with different superscript letters in a row are significantly different ($p < 0.05$). *[Variations mensuelles des valeurs de l'index somatique (SI) en fonction du sexe de* L. cephalus *de la rivière Çoruh. Les différences significatives (p < 0,05) des valeurs moyennes sont signalées par différentes lettres.]*

Month	Male		Female		Juvenile		Overall		*
	N	$\overline{SI} \pm SE$	N	$\overline{SI} \pm SE$	N	$\overline{SI} \pm SE$	N	$\overline{SI} \pm SE$	
March	92	1.23 ± 0.017	57	1.26 ± 0.022	50	1.16 ± 0.020	199	1.20 ± 0.011	ac
April	87	1.19 ± 0.015	31	1.21 ± 0.034	103	1.15 ± 0.016	221	1.17 ± 0.011	b
May	99	1.31 ± 0.018	56	1.35 ± 0.021	79	1.16 ± 0.019	234	1.27 ± 0.012	d
June	55	1.27 ± 0.017	48	1.36 ± 0.024	56	1.25 ± 0.017	159	1.29 ± 0.012	d
July	116	1.26 ± 0.016	31	1.27 ± 0.025	75	1.18 ± 0.017	222	1.23 ± 0.011	c
August	34	1.24 ± 0.015	25	1.24 ± 0.040	60	1.15 ± 0.019	119	1.19 ± 0.014	abc
September	19	1.30 ± 0.026	22	1.33 ± 0.033	77	1.15 ± 0.016	118	1.20 ± 0.015	abc
October	56	1.21 ± 0.020	31	1.24 ± 0.024	108	1.16 ± 0.020	195	1.18 ± 0.013	ab
November	23	1.20 ± 0.022	5	1.22 ± 0.012	23	1.17 ± 0.037	51	1.18 ± 0.019	ab
December	-	-	-	-	-	-	-	-	
January	-	-	-	-	-	-	-	-	
February	18	1.25 ± 0.053	3	1.16 ± 0.074	49	1.05 ± 0.019	70	1.10 ± 0.022	e
Mean	599	1.25 ± 0.007	309	1.29 ± 0.010	680	1.16 ± 0.006	1588	1.22 ± 0.004	
*		a		b		c			

Table IV. - Spatial variability of parameters of length-weight relationships for sexes of European chub from Upper Çoruh River. * indicates isometric growth. All the other cases imply positive allometric growth. *[Variations spatiales des paramètres des relations taille-poids selon le sexe de* L. cephalus *de la rivière Çoruh. * indique une croissance isométrique. Tous les autres cas montrent une croissance allométrique positive.]*

Site	Sex	N	a	b ± SE	R^2	Confidence limits (95%) of b	T value of difference from 3.0
Site 1	Male	187	0.007	3.234 ± 0.034	0.97	3.155-3.312	5.55
	Female	107	0.008	3.201 ± 0.050	0.98	3.101-3.301	4.57
	Juvenile	276	0.009	3.116 ± 0.027	0.98	3.062-3.171	4.40
	Overall	570	0.009	3.136 ± 0.013	0.99	3.111-3.162	9.90
Site 2	Male	72	0.008	3.160 ± 0.028	0.98	3.104-3.216	2.80
	Female	16	0.009	3.142 ± 0.035	0.98	3.073-3.212	1.15*
	Juvenile	149	0.007	3.146 ± 0.025	0.98	3.095-3.196	3.97
	Overall	237	0.009	3.170 ± 0.017	0.99	3.135-3.204	6.57
Site 3	Male	208	0.008	3.157 ± 0.037	0.97	3.082-3.231	4.13
	Female	133	0.010	3.112 ± 0.055	0.98	3.002-3.224	2.82
	Juvenile	280	0.010	3.075 ± 0.029	0.97	3.017-3.133	2.30
	Overall	621	0.009	3.169 ± 0.013	0.98	3.143-3.195	9.33
Site 4	Male	107	0.012	3.039 ± 0.045	0.97	2.949-3.130	0.72*
	Female	54	0.008	3.167 ± 0.052	0.98	3.062-3.272	2.59
	Juvenile	346	0.012	3.021 ± 0.026	0.98	2.970-3.073	0.86*
	Overall	507	0.008	3.193 ± 0.013	0.98	3.167-3.219	11.91
Site 5	Male	112	0.016	2.929 ± 0.072	0.97	2.783-3.075	1.37*
	Female	37	0.009	3.109 ± 0.082	0.99	2.933-3.286	2.05
	Juvenile	112	0.009	3.113 ± 0.031	0.99	3.051-3.175	3.80
	Overall	261	0.009	3.131 ± 0.016	0.99	3.098-3.164	6.96

1997b; Türkmen *et al*., 1999, Yildirim *et al*., 2001; Erdoğan *et al*., 2002; Yildirim *et al*., 2006; Arslan and Yildirim, 2007). High correlation between condition and somatic index with great similarity in the seasonal cycle among juveniles and adults suggested that seasonal variation in European chub was probably more related to environmental condition than to the reproduction issue as reported by Cambray and Bruton (1984) for *Barbus anoplus*, Encina and Granado-Lorencio (1997a) for *Leuciscus pyrenaicus*, Encina and Granado-Lorencio (1997b) for *B. sclateri*, Yildirim *et al*. (2006) for *B. plebejus escherichi*. Although condition and somatic index cycle in juveniles displayed common seasonal pattern throughout the year, those among sites exhibited different cycle in which the highest value in K and SI for site 1 were experienced in summer and in late spring for sites 3 and 5. This may be attributed to both food availability in sites and intra/inter species competition. Seasonal fluctuation throughout the year in K and SI for adults

Table V. - Seasonal variability of parameters of length-weight relationships for sexes of European chub from Upper Çoruh River. * indicates isometric growth. All the other cases imply positive allometric growth. *[Variation saisonnière des paramètres de la relation taille-poids selon le sexe de* L. cephalus *de la rivière Çoruh. * indique une croissance isométrique. Tous les autres cas indiquent une croissance allométrique positive.]*

Sex	Season	N	a	b ± SE	R^2	Confidence limits (95%) of b	T value of difference from 3.0
Male	E. Spring	194	0.007	3.234 ± 0.039	0.97	3.155-3.312	5.71
	L. Spring	181	0.009	3.160 ± 0.028	0.99	3.104-3.216	6.73
	Summer	165	0.009	3.157 ± 0.037	0.97	3.087-3.231	3.62
	Fall	95	0.012	3.039 ± 0.045	0.97	2.949-3.130	0.71
	Winter	51	0.001	2.974 ± 0.069	0.97	2.835-3.114	0.35*
	All Male	686	0.008	3.164 ± 0.018	0.99	3.129-3.199	23.88
Female	E. Spring	89	0.008	3.201 ± 0.050	0.97	3.102-3.300	3.35
	L. Spring	123	0.009	3.142 ± 0.035	0.99	3.072-3.212	4.93
	Summer	62	0.009	3.112 ± 0.055	0.98	3.001-3.223	1.95*
	Fall	58	0.009	3.167 ± 0.052	0.98	3.062-3.272	2.77
	Winter	15	0.10	3.109 ± 0.081	0.98	2.932-3.286	0.89*
	All Female	347	0.008	3.176 ± 0.021	0.98	.129-3.199	13.40
Juvenile	E. Spring	272	0.009	3.116 ± 0.027	0.97	3.061-3.170	3.49
	L. Spring	246	0.009	3.146 ± 0.025	0.98	3.095-3.196	5.08
	Summer	240	0.011	3.075 ± 0.029	0.97	3.017-3.133	2.15
	Fall	252	0.011	3.021 ± 0.026	0.98	2.970-3.073	0.77*
	Winter	153	0.009	3.113 ± 0.031	0.98	3.051-3.170	3.13
	All Juvenile	1163	0.010	3.102 ± 0.012	0.99	3.078-3.125	11.10
Overall		2196	0.008	3.162 ± 0.006	0.99	3.149-3.174	23.88

Table VI. - Some physical characteristics of the study area. *Anonymous (1996). *[Caractéristiques physiques majeures de la zone d'étude.]*

Parameters	Sites				
	Kirik	Maden	Bayburt	Kirazli	Nihak
Altitude (m)	2100	1700	1550	1250	950
Water temperature (°C) Min-Max (mean)	0-20 (9.3)	0-21 (10.5)	0-21 (10.5)	1-23.5 (12.5)	1-25 (13.9)
Width (m)	4-5	10-12	30-40	35-45	40-50
Snowy months	October-March	October-March	October-March	December-February	January-February
Ice-covered period	December-February	December- January	December- January	December- January	December- January
Substrate	Sand-gravel	Sand-gravel	Sand-gravel	Pebble-cobble	Pebble-cobble
Discharge (m^3s^{-1})*	N/A	4.79-50.4	N/A	12.0-134.0	17.4-214.0
Mining sand	Absent	Intensively	Rarely	Rarely	Seldom
Residence	8-10 villages	8-10 villages	Bayburt province and its villages	Pazaryolu town and its villages	Ispir town and its villages
Industry	Absent	Absent	Present	Absent	Absent
Domestic waste	Present	Present	Present	Present	Present
Agricultural lands	Pasture areas	Small-scale agricultural areas	Large agricultural areas	Medium-scale agricultural areas	Small-scale agricultural areas

displayed different variation. In early and late spring, K and SI were more separated than that in other season. This was good agreement with reported by Encina and Granado-Lorencio (1997a, 1997b) and Yildirim *et al.* (2006). This was probably related to gonadal development and spawning in a similar way reported by Rajasilta, (1992), Encina and Granado-Lorencio (1997ab) because *Leuciscus cephalus* in European and Turkey streams reproduces from April to August depending on water temperature (Penaz *et al*., 1978; Ünlü and Balci, 1991; Ekmekçi, 1996; Bircan and Ağirağaç, 1995; Türkmen *et al*. 1999; Erdoğan *et al*., 2002).

The exponent *b* of LW-R often has a value close to 3 with a variation between 2 and 4 (Tesch, 1971). Juveniles of many species displayed different growth characteristic or *b* value of L-RW because they do not reach constant body shape as reported by Tsoumani *et al*. (2006). The parameters of L-WR can be affected by many factors such as stomach fullness, diet, season, habitat, gonad maturity, sex (Tesch, 1971; Bagenal and Tesch, 1978; Weatherley and Gill, 1987). Different temporal growth characteristic for European chub may be related to gonadal development and spawning, but spatial variation may be attributed to water temperature and food availability as reported by Karakulak *et al*. (2006) and Hossain *et al*. (2006).

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